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INFLUENCE OF TEMPERATURE ON THE COPULATION DURATION OF *LYCOSA MALITIOSA* TULLGREN (ARANEAE, LYCOSIDAE)[1]

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ABSTRACT

The copulation duration (CD) of 99 copulations of *Lycosa malitiosa* recorded within a wide range of temperatures was analyzed. Copulation duration (minutes) varied inversely with temperature (Tm, in degrees Celsius). The best mathematical function statistically adjusted to the values obtained was: CD = 212.73 - (4.92) Tm. There was no influence of copulatory experience of the male on CD; a possible influence of humidity on CD is not clear.

INTRODUCTION

If environmental temperature rises, the metabolic rate of poikilotherms increases according to the principles formulated by Van't Hoff and Arrhenius for chemical reactions. The most typical relationship between both processes is of the exponential type; however, a linear model is frequently used over a restricted range of temperature. It has been estimated that metabolic activity doubles if the environmental temperature rises about 10°C. If temperature is related to the duration of any metabolic process, this relationship should be inverse. These concepts have been applied in general terms to several physiological processes (excepting biorhythms) and to the development of poikilotherms (Wigglesworth 1965, Prosser 1973). Behavioral activity does not seem to be modified regularly by temperature, and experiments reported up to now have been planned to support the view that kinetic activities and taxes could be triggered or modified by thermal influence.

The influence of temperature on lycosid spiders was studied as to metabolism (Miyashita 1969, Anderson 1970, Humphreys 1975a and 1977a), feeding levels (Edgar 1970, Humphreys 1977b, Aitchison 1981), care of the cocoon (Fujii 1978), and autecology (Humphreys 1974 and 1975b). The influence of temperature on the beginning of sexual activities as well as on the duration of the breeding season has been studied by several authors in several spider species. Costa (1975, 1979) studied the sexual behavior of *Lycosa malitiosa* Tullgren at varying temperatures during the year and suggested (Costa

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1979) that copulation duration is modified by temperature changes. Costa and Sotelo (1981) reported in a preliminary paper a correlation between copulation duration and environmental temperature. The present paper provides a more complete account of the same subject.

Copulation duration sometimes has been useful for taxonomic differentiation of spiders at the level of family or genus (Rovner 1973, 1974), and also to compare species within a genus (Engelhardt 1964). Otherwise, copulation duration could be related to energetic cost, fertilization level, risk of predation and other adaptative aspects of the species. Temperature and other factors that may induce changes in copulation duration therefore have to be examined in detail. For instance, Jackson (1980) showed that variablility of copulation duration in *Phidippus johnsoni* (Salticidae) is related to the varied mating tactics used by the individuals of this species, depending on whether copulation occurs inside or outside the nest. Costa and Sotelo (1981) also suspected that the copulation duration of *L. malitiosa* does not depend on variations in humidity. Another factor, previous copulatory experience, had not been investigated until the present study.

The purpose of the present research was to ascertain the degree of correlation between copulation duration and environmental temperature in *L. malitiosa,* and to determine if copulation duration is affected by humidity or previous copulatory experience of the male. The main objective was to determine the mathematical function representing the relationship between copulation duration and temperature. Knowledge of this function will provide a better basis for the possible use of copulation duration as a character in the taxonomy of certain groups of spiders.

GENERAL METHODS

Collection, breeding, and observation methods applied to the study of *L. malitiosa* were described in a previous paper (Costa 1979). Ninety-nine copulations recorded from 151 individuals (67 males and 84 females) were analyzed. In 39 copulations virgin males were presented to females four days after the male's final molt. After mating, males were kept isolated for a 45-hr period before they were presented again to females. Under these conditions 45 males copulated once, 15 males copulated twice, 5 males copulated 3 times, one male copulated 4 times, and one male copulated 5 times. Seventy females copulated only once, 13 females copulated twice, and one female copulated 3 times. Copulation duration (CD) was measured from the beginning of mount up to the end of dismount. The mean duration was 98.1 ± 28.6 min (range: 38.7 to 198.5).

Temperature and humidity were continuously registered during the entire period of captivity (Lufft hygrothermograph, type 8140). Both factors were measured during copulation with a mercury-thermometer and a hair-hygrometer on the floor of a cage next to the observation cage. During copulation, the temperature was 22.7 ± 4.3°C (range: 14 to 33.3°C), and the mean relative humidity was 62.3 ± 10.9% (range 36 to 91%). Light intensity and photoperiod were kept constant. Illumination during copulation was provided by a fluorescent tube (1100 lux).

After experimentation all specimen were deposited in the arachnological collection of the "Museo Nacional de Historia Natural", Montevideo, Uruguay (lot number 854).

In all statistical tests, the minimal level for rejecting the null hypothesis was 0.05.

COPULATION DURATION AND TEMPERATURE

Methods and Results.–To examine the possible dependence of CD on environmental temperature, a Chi-square test was applied to 99 pairs of values obtained; the population of data was divided into four groups using the mean values of both variables as the limit value for each group. The result was: Chi-square = 20.78, $P < 0.01$.

To test the type of relationship occurring *in copula* between both parameters, the linear relationship of the 99 individual pairs of values was examined. Regression equation: $Y = 189.78 - (4.04)X$, $t_b = 7.37$, $P < 0.001$; correlation coefficient: $r = -0.60$, $t_r = 7.37$, $P < 0.001$. Individual data of both CD and temperature were also grouped in class intervals of 1°C. The values of each variable within each interval were averaged. The correlation coefficient was higher than in the former case: $r = -0.86$, $t_r = 6.98$, $P < 0.001$; regression equation was: $Y = 212.73 - (4.92)X$; $t_b = 6.98$, $P < 0.001$ (Fig. 1).

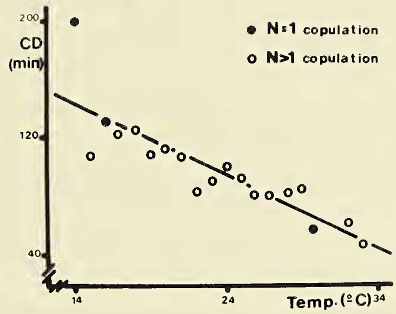

Fig. 1.–Copulation duration (CD) in *Lycosa malitiosa* in relation to environmental temperature. Ninety-nine pairs of values were recorded. The mean values of CD and temperature are plotted within class intervals of 1°C. The correlation between both variables is: $r = -0.86$, $t_r = 6.98$, $P < 0.001$. The equation of the regression line is: $Y = 212.73 - (4.92)X$; $t_b = 6.98$, $P < 0.001$.

Discussion.–The data above indicate that CD in *L. malitiosa* is inversely related to environmental temperature. The influence of temperature on copulation follows a course which is similar to the influence exerted on several physiological and developmental processes in poikilotherms (providing that the temperature range does not go below 14°C or above 33.3°C). Metabolic rate changes caused by thermal variations may directly affect the temporal characteristics of copulation, though not necessarily the basic copulatory pattern of the species. Research now in progress indicates that the number of palpal insertions and the copulatory side changes are constant in spite of temperature changes. However, a certain degree of variability in the distribution of the units integrating the partial models of copulation described by Costa (1979) is noted.

The wide dispersion found among the CD values corresponding to each temperature interval indicates that CD also varies among individuals. The highest correlation coefficient obtained (-0.86) shows the importance of employing mean values from a large population. In this way the results are more valuable if CD is used for taxonomic purposes. The regression equation developed here may be used to characterize the species more accurately than would any particular value of CD and its corresponding temperature. For example, the copulation time of *L. malitiosa* at 19°C is twice as long than at 31°C (120 min and 60 min, respectively). The slope of the regression line ($b = 4.92$) indicates directly, in minutes, the increase or decrease expected of CD when temperature decreases or increases 1°C, respectively.

COPULATION DURATION AND ENVIRONMENTAL HUMIDITY

The possible relationship between CD and relative humidity during copulation was examined by applying the Chi-square test to the 99 pairs of values registered. Data were

Table 1.—Multiple regression among copulation duration (dependent variable), temperature and humidity (independent variables) (N = 99). Analysis of variance.

Multiple correlation coefficient: r = 0.59995; P < 0.01.

Source of variation	Degrees of freedom	Sum of squares	Mean square	F	P
Regression	2	28973.98	14486.99	26.99	< 0.01
Deviations	96	51523.12	536.70		
Total	98	80497.09			

divided into four groups according to the mean values recorded. The result was: Chi-square = 0.50, 0.70 < P < 0.80.

Using the same 99 pairs of values a possible correlation between CD and relative humidity was tested. The result was: r = 0.014, t_r = 0.13, 0.80 < P < 0.90; regression coefficient: b = 0.036, t_b = 0.13, 0.80 < P < 0.90. Individual data of both CD and humidity were also grouped in class intervals of 3% humidity. The values of each variable within each interval were averaged. The result was: correlation coefficient, r = 0.12, t_r = 0.50, 0.60 < P < 0.70; regression coefficient, b = 0.11, t_b = 0.50, 0.60 < P < 0.70.

A possible correlation between temperature and humidity during the 99 copulations was also tested. The result was: r = -0.063, t_r = 0.62, 0.50 < P < 0.60; b = -0.16, t_b = 0.62, 0.50 < P < 0.60.

A multiple regression and an analysis of variance were applied on CD (dependent variable), temperature and humidity (independent variables). Results are shown in Table 1.

The non-significant partial correlations (humidity and CD, as well as humidity and temperature) suggest no influence, directly or indirectly, of environmental humidity on the CD of *L. malitiosa.* However, the analysis of variance on the multiple regression indicates a slight influence of humidity on CD.

COPULATION DURATION AND PREVIOUS COPULATORY EXPERIENCE OF THE MALES

The CD of a group of 20 previously unmated males ("virgin" males) was compared to the CD of a group of 13 males which had previously copulatory experience ("experienced" males). Temperature conditions were the same in both cases (Table 2). The Student t-test (non-paired t-test, Cramer 1956) revealed no significant difference, so

Table 2.—Analysis of the possible influence of the copulatory experience on copulation duration of *L. malitiosa* through the use of the Student t-test.

Previous copulatory experience of males	CD (min) $\bar{X}$ ± SD	Temperature (°C) $\bar{X}$ ± SD
Virgin males (N = 20)	90.9 ± 24.8	22.5 ± 1.5
Experienced males (N = 13)	101.7 ± 32.0	22.4 ± 1.6
t-test	t = 1.03; 0.30 < P < 0.40	t = 0.18; 0.70 < P < 0.80

copulatory experience of males would not have influence on CD. However, some preliminary observations suggest a decrease in CD in males which have copulated less than 24 hr before being mated again with a female (fatigue?).

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